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How to make a paper helicopter

Here is an unusual paper flying model, designed by Richard K Nen of Wilmington, Ohio, USA, for a competition organised by the *Scientific American* magazine. This is what it looks like.

What you need
a piece of paper 21.5 cm by 4.5 cm
a pencil
a ruler
a pair of scissors

What you do

7.8cm	2.7cm	8.8cm	2.2cm
B		D	E
A		C	
21.5cm			

Cut along all the solid lines. Fold part A forwards, then fold part B backwards. Fold C in and overlap by folding D on top. Fold E up. Launch the helicopter by dropping it from a height. What sort of movement does the helicopter make through the air?

How to make a kite

What you need
newspaper or old pillow case
2 pieces of cane or thin dowel
a ball of string
some pieces of paper to make a tail
glue
a pair of scissors
thread

What you do

Make rod AB twice as long as rod CD. Fasten them together with string at E, with AB on top. Tie a long piece of thread firmly to rod AB at A, take it to D and tie again firmly, and so on round the kite so that you have a diamond-shaped frame of thread A D B C A. Use this frame as a pattern and cut out the shape in paper or cloth, allowing an extra 2.5 cm all round. Fold over the extra 2.5 cm along the thread and glue down, trapping the thread. Make a tail by tying a piece of string round a series of pieces of paper to make bows. Fasten it to the kite at B. Turn the kite over and pierce a small hole at F and H. Thread a piece of string through each hole and tie firmly to rod AB at F and H. Join the two pieces of string at G and attach your main reel of string at G.

Most of the equipment you will need to carry out the experiments in this book is easy to collect and safe to use. Don't forget a notebook — one of the important things about experimenting is to note what happens so that you can compare it with what happens next time. Scientists always keep a record of their research projects for this reason, so why not do the same?

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Air

by JOHN PAULL

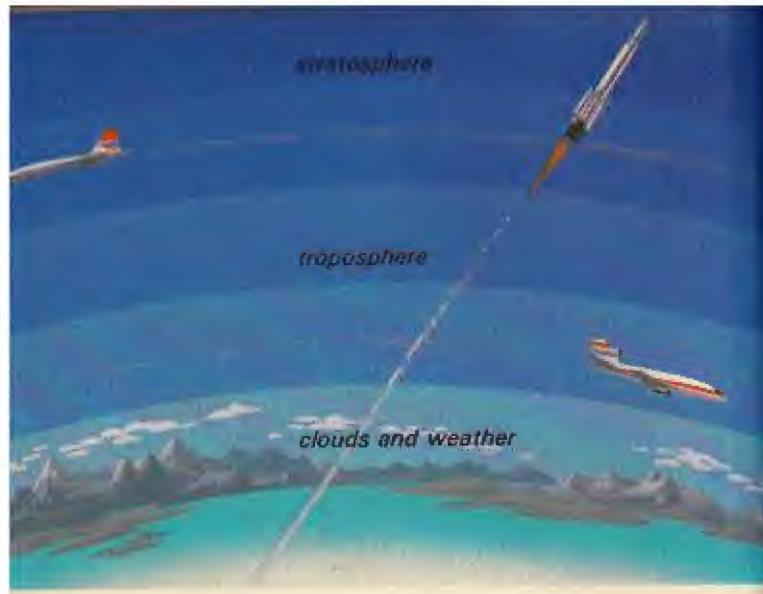
illustrated by ROBERT AYTON



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Ladybird Books Loughborough



Air is all around us, surrounding our planet like a thick blanket. You can feel it hitting your face, hands and legs on windy days. You can see it blowing leaves, swirling chimney smoke, and flapping flags.

Before 1670, great thinkers of the time thought that air was a pure substance. They were astounded when several scientists working together in a small laboratory discovered that air wasn't pure at all, but contained at least two different gases. This led other scientists to investigate, and eventually they realised that air was a mixture of more than two gases. Today we know that air is a combination of gases. It contains about 21% oxygen, 78% nitrogen and nearly 1% argon. Besides these three gases, it also contains small quantities of carbon dioxide and hydrogen, and minute traces of four rare gases called helium, neon, xenon and krypton.

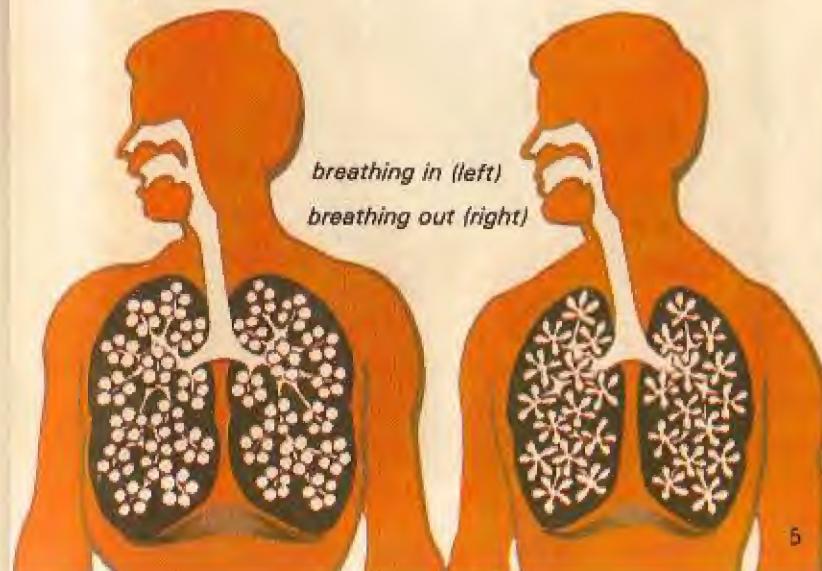
Oxygen is the life-giving gas of the air. The belt of air that envelops the earth is about 72 kilometres thick, but

the gases are not equally distributed. In fact, at high levels above the ground the air thins out considerably and does not contain enough oxygen to support life. Aircraft pilots have life support systems, otherwise they would collapse through oxygen starvation. Even mountaineers climbing the high peaks scattered around the world need an oxygen supply as they ascend, because the level of oxygen quickly thins out and breathing becomes very difficult.

Air for life

Stop breathing just for a second. Concentrate hard. Now breathe in deeply through the mouth. Can you feel the air hitting the inside of your cheeks? Where does the air go next?

When we breathe in, air is drawn through the nose and mouth, quickly moves down the windpipe and enters a pair of large sponge-like organs in our chest called the lungs.



We breathe out as regularly as we breathe in, getting rid of the unwanted oxygen (we don't use all of it), nitrogen (which we don't use at all), and carbon dioxide. This gas is the waste product of breathing. A group of people sitting in a poorly ventilated room with the windows closed will soon increase the carbon dioxide in the air, which will make them feel tired and drowsy. Air in crowded cities, where chimneys and cars belch out smoke, is not so pure and healthy as country air. City air would soon be unfit to breathe if it were not for large surrounding areas of parkland, forests and countryside. Trees, bushes and plants take carbon dioxide from the air to manufacture food. This food making process, called *photosynthesis*, uses up carbon dioxide, and oxygen is made as a waste product, joining the air for our use.



We can show the presence of carbon dioxide in the air we breathe out by blowing through a straw into a jar of lime water. Lime water is made by adding a teaspoonful of garden lime to water and stirring until it has dissolved; let the lime settle and pour off the limewater solution. Carbon dioxide turns lime water cloudy. You will have to blow quite hard, though, because you do not breathe out much of the gas each time and it takes quite a lot of carbon dioxide to colour lime water.

Can you work out how many times you breathe out in a minute? How many times do you breathe out in an hour?

Plants, like animals, take oxygen directly from the air, but fish and other freshwater and seawater creatures take their air from water. Air is dissolved in water. Fish pass the water through their mouths and out through the gills where oxygen is removed and added to the blood. The actual amounts of air dissolved are really quite small. There is only about a cupful of air in a large tropical fish tank.



Japanese Tang

Finding out about air through experiments

Air is everywhere. We know that it is around us all the time because we feel it on our bodies and in our mouths. But how can we prove that air is around us? *Where* is air? It is in the most surprising places.

Half-fill a plastic bucket with cold, clear tap water and plunge a narrow-necked plastic bottle down under the surface of the water. Tilt it so that the water trickles into the bottle. What happens? Do you think the bottle was really empty? It was filled with air which rushed out as the water ran in. The air comes out in bubbles which pop as they reach the water surface and disappear. Take the bottle out of the bucket and dig up a lump of soil from the garden with a trowel. Carefully put the lump in the bottom of the bucket. What do you notice that tells you that air was inside the lump of soil? Can you catch the stream of bubbles that come from the soil, in a bottle?



You can repeat this experiment with a brick tied to a long length of cord. Gently lower the brick into a bucket of clean water and let it rest on the bottom. Is there any evidence that air was inside the brick? Like the soil, bricks contain minute air pockets, but not enough to make the brick float. Air occupies every space it can find, no matter how large or how small. Sponges we use in the bath contain air and float on water, but if they are squeezed under the surface, the air pockets fill with water, increasing the sponge's weight. Can you find anything else that has air pockets? Does a sheet of newspaper have air pockets? A bar of soap? What happens when you pour a handful of sand into a bucket of water?

Air is where you least expect it. Fill a glass with cold water and let it stand on a sunny windowsill for a few hours. What do you notice? Can you see the tiny streams of bubbles rising to the top of the surface? The water contains dissolved air and as the sun warms the water, some of the air escapes.

Air and burning

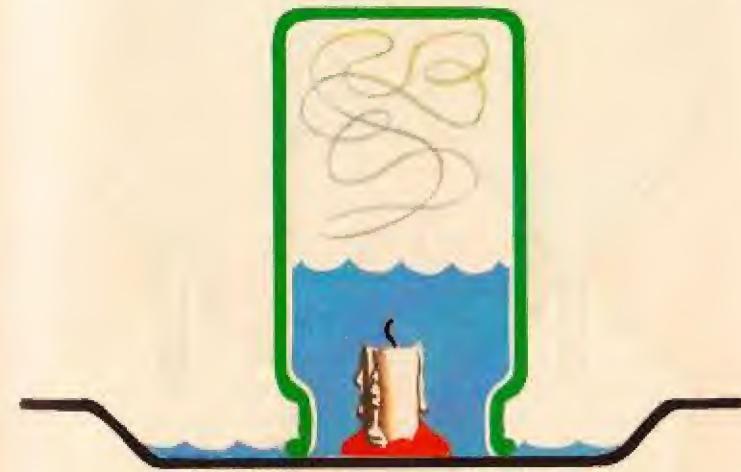
Fires need air. Early man realised that air has something to do with burning. Cavemen discovered that by blowing and fanning a spark the flames would soon grow, and that open fires burned better and more brightly with a good supply of air.

The following experiments show why air is important when things burn. (A grown-up should always be present when you do these experiments.) Collect together a small candle, a tin soup plate, and three wide-necked jars of different sizes. Use a piece of 'Plasticine' to secure the candle to the centre of the tin plate. Light the candle, and when the flame is burning strongly, put one of the glass jars over the top and watch what happens. After a while the height of the candle flame shortens, and then goes out altogether. All the oxygen in the air has been used up.



Now that we know that flames need oxygen from the air, the idea of blowing on a fire to help it to burn better makes sense. Blowing brings extra air to a fire, and therefore a fresh supply of oxygen, which feeds the fire. Some people use bellows to blow on their fire to get it going. At the same time, though, violent currents of air can put fires out by blowing away the air surrounding the flame. This is why candle flames go out when you blow at them.

Repeat the experiment, but this time pour some water onto the tin plate and see what happens. Now do it again with the different sized jars, and you will notice that the candle flame goes out in all the containers; that it burns longer in the larger jars; and that the water in the plate goes up into the jars as the candle burns. Inside each jar the flame went out when it used the oxygen in the air. Without oxygen it could not burn. The candle burned



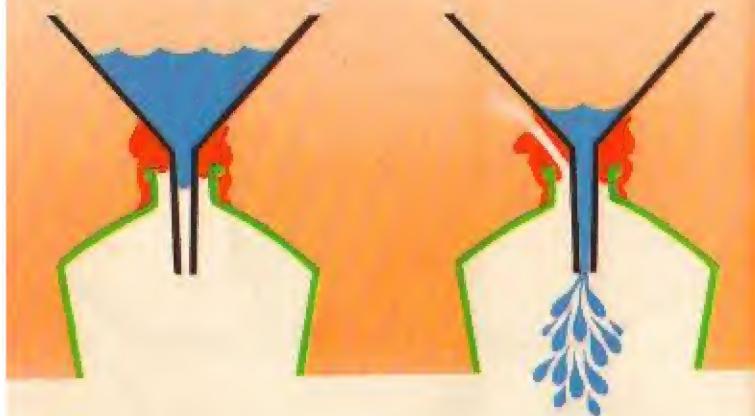
longer in the larger jars because there was more air, and therefore more oxygen, inside the containers. The water went up into the jars to fill the space left when the oxygen was used up by the candle flame.

Try the experiment again, and this time note how long it takes for the flame to go out in each jar, and measure how far up the water rises when the flame is burning. Does the water always rise to the same mark when the experiment is repeated with the same jar?

To show that air takes up space

Since air is real, it must take up space. Soap bubbles floating in a washing-up bowl are little bags of air taking up space inside a film of soap solution, but there are more scientific ways to demonstrate that air occupies space.

You need an empty plastic hair shampoo bottle and a plastic funnel. Rest the funnel inside the neck of the bottle and fill the space around the funnel with 'Plasticine'. Make sure that the 'Plasticine' is pushed firmly into place so that the funnel fits snugly into the bottle neck. Now pour a small amount of water into the



funnel. What do you notice? Can you make the water enter the bottle? Carefully push a long thin nail through the 'Plasticine' so that air can get into the bottle neck. Now what happens when you pour the water into the funnel? The water will only go into the bottle if the air can go somewhere else. The air is pushed through the hole in the 'Plasticine'.



Here is another experiment. Float a cork in a washing-up bowl half-full of water. Now lower a clear plastic drinking mug downward over the cork. What happens? Does the cork get wet? Try it again, and this time make a small sail for the cork. Does the sail get wet? The air in the mug pushes the water down.

Now fill the bowl nearly full of water and put a clear plastic mug, mouth downward, into the bowl. With your other hand, lower another mug into the bowl. Tilt its mouth upwards so that the water rushes in and hold it above the first mug with its mouth pointing downwards. Slowly tilt the first mug to let the air bubbles escape. Can you fill the second mug with air from the first mug?

Air can be squeezed or compressed. When we blow up the tyres of our bikes, we force air into a confined space under pressure. If you press your thumb on a bike tyre, the air inside bubbles around and settles elsewhere until you release your thumb.



How much does air weigh?

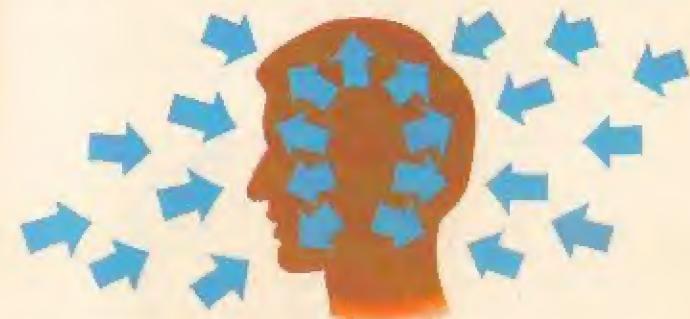
Now that we have proved that air is real and takes up space, we know that it must have mass, i.e. weigh something. The mass of air around us varies under different conditions. (We use the word *mass* here because the more usual word *weight* is not strictly scientific. We often find the mass of an object by 'weighing' it against a known mass, such as a 1 kg, which would suggest that *weight* and *mass* were the same, but this is not scientifically accurate.) Scientists, through careful experimentation, have worked out that on a still day, 1 cubic metre of air has a mass of about 1300 g. The mass of all the air in an ordinary front room of a house is about the same as a full large sack of potatoes.

How can we prove that air has weight? Drive a long thin nail through the centre of a stick about 1 metre long and balance the stick by resting the nail across the rims of two empty tins. Hang a balloon from each end until they balance. Take one balloon away and blow it up as hard as you can, then replace it on the end of the stick. What do you notice?

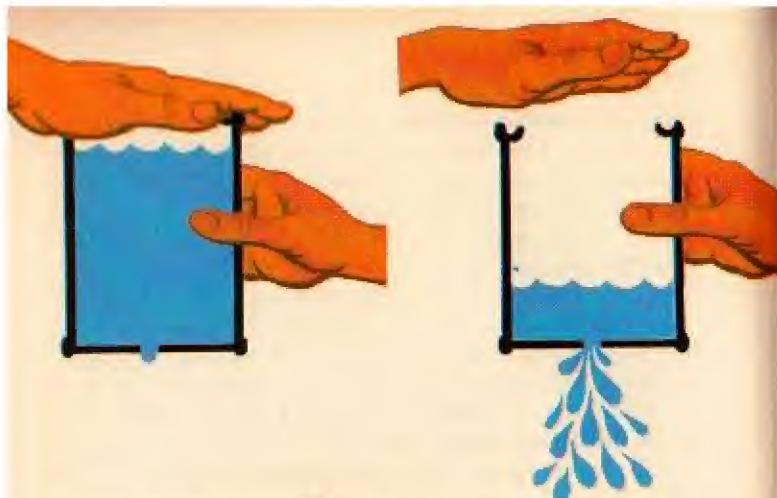


Air pressure

When you swim under water you can feel the pressure of the water on your body. The deeper you go, the greater the pressure. Air, too, exerts pressure. The total pressure of the massive air belt around the earth is enormous. It produces, at sea level, a pressure of 3 kg per sq cm. This means that on an ordinary person's skin, there is a total pressure of air of about 12000 kg. Why doesn't this crush us flat? After all, it is roughly the pressure exerted by two full-grown elephants. Fortunately, the air presses in all directions at the same time and does not pinpoint one spot. As the load is spread, there is little strain on our elastic skin. Also our bodies are filled with air which exerts the same internal pressure as the air outside.



Up in the sky, way above sea level, though, there can be problems. When balloonists reach great heights in their hot air balloons, the surrounding air is thin and the air pressure is less. Because the pressure of air inside our bodies is greater than the air pressure outside, frightening things sometimes happen. It has been known for balloonists to experience the very nasty sensation of blood oozing out of their ears. Aircraft flying at high altitudes have pressurised cabins so that people on board can breathe easily and not feel the effects of the reduced pressure outside.



Experiments using air pressure - I

Air pressure is one of the most fascinating aspects of studying air. There are several interesting experiments that are easy to perform.

To demonstrate the effect of air pressure, make a hole with a nail in the bottom of a tin. Fill the tin with water. (You had better stand near a sink!) Now hold the palm of your hand tightly over the top of the tin, and keep your fingers tightly together so that air cannot creep through. What do you notice? The water will stop running out of the hole. Now take your hand away, and the water will begin to flow out again. What do you think causes this?

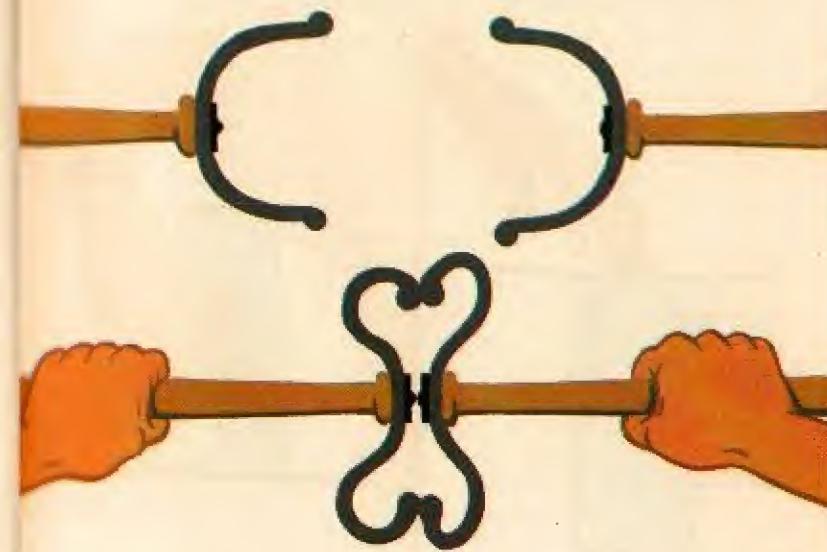
Find a clean jam jar with a screw lid, make one small hole in the lid with a nail, then fill the jar right up to the top with water. Screw on the lid. Try to pour the water through the hole. Can you do it? Make a second hole and try again. Does it make a difference? Why?

Sink a plastic tumbler in a bowl of water. Make sure that the tumbler fills with water. Now lift the tumbler up with its mouth pointing to the bottom of the bowl, until the tumbler is nearly out of the water. What happens? Do

you see how you can lift the water in the tumbler? Why doesn't the water run out?

Rubber plungers are used in kitchens to unblock sinks. If you can get hold of a pair of them, try this experiment. Wet the rims of the two plungers and press the rubber cups together so that they fit snugly. Now try to separate them. Can you do it? Why is it so difficult to pull them apart? You will have to slide them apart.

When you have finished these experiments, just take a minute to think about what has happened. Air exerts a considerable pressure under normal conditions. When it is compressed, the pressure is increased. If you blow up a balloon and tie the end so that no air can escape, you have a bag of air under high pressure. Press your finger into the balloon, then take it away quickly. Notice how the stretched rubber instantly fills out — because the air pressure inside the balloon is greater than the air pressure outside.



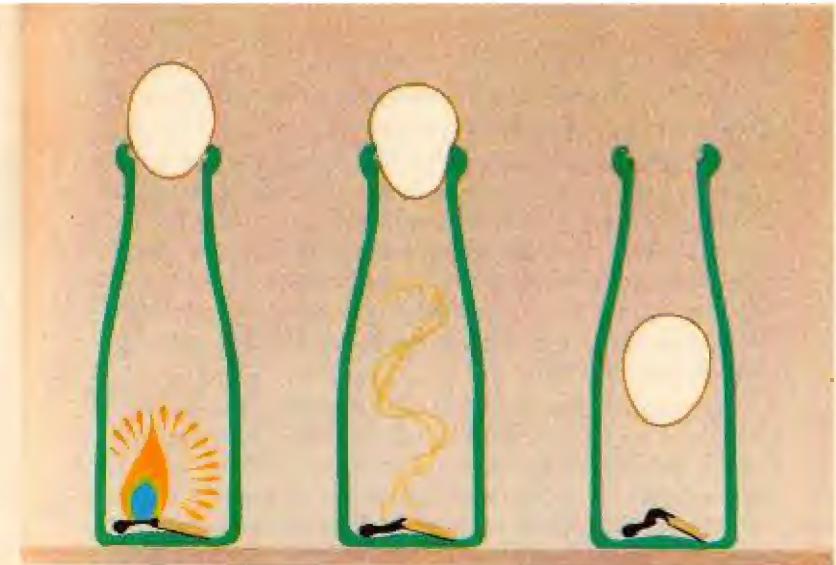
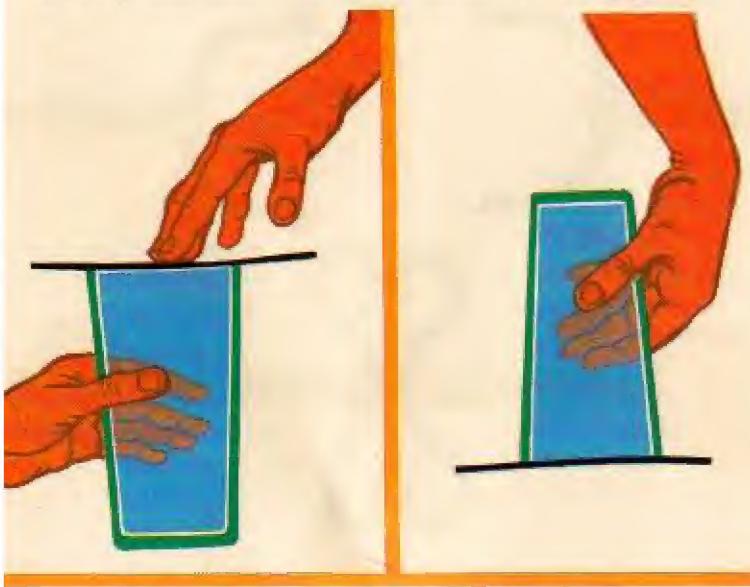
Experiments using air pressure - II

Here are two well known air pressure experiments that will amuse and fascinate your friends.

Fill a plastic tumbler right up to the top with water, and slide a piece of smooth card about the size of a postcard over the top. Make sure that there is water at the very top of the tumbler, actually touching the card so that there isn't any air underneath. Keep your hand pressed on the card, and turn the tumbler upside down. Now move over to a sink, and take your hand away. What happens? If you have done everything properly, the card will stay in place.

The pressure of the outside air acts against the card and forces it against the tumbler, because it is stronger than the pressure of the water. Don't give up if it doesn't work first time. Try it again until you get success.

Find an egg that fits snugly into the mouth of a large milk bottle. Boil the egg for about ten minutes so that it is really hard, then cool it under the cold water tap. Take



off the shell, making sure you do not puncture the egg white. Rest the peeled egg on the milk bottle, light a match, and move the egg gently so that the match can be dropped inside the bottle. Quickly replace the egg in its original position. The match continues to burn until it uses up all the oxygen inside the bottle, and the egg slowly gets sucked into the bottle *intact*. The air pressure is decreased inside the bottle because the oxygen has gone, and as the pressure of the air is now greater outside, the egg is pushed inside the bottle.

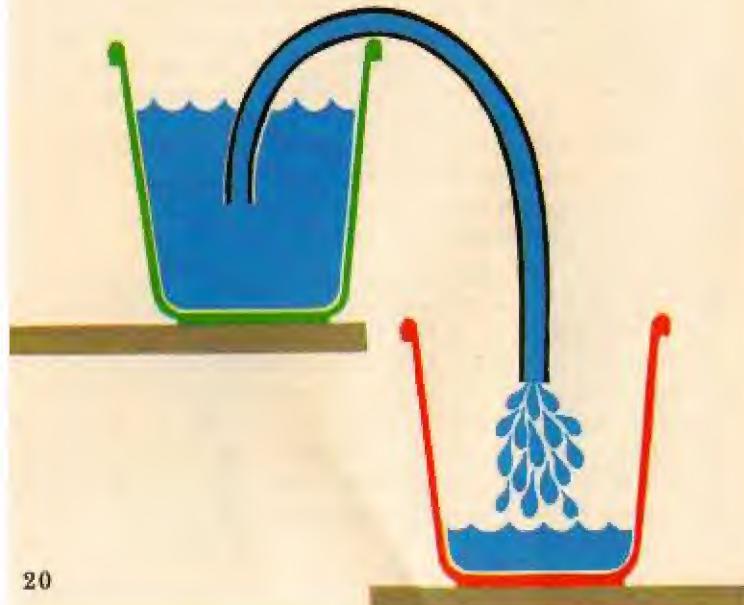
Now you are left with the egg lying on the bottom of the milk bottle. How do you get it out? It isn't easy, but it *can* be done. Hold the bottle to your mouth and blow as hard as you can. This should build up the pressure inside the bottle and when you have blown enough to make the pressure inside greater than the air pressure outside, the egg will slip out. If it doesn't work first time, don't despair. It sometimes works better if you blow through a straw into a bottle. See which way works best.

Siphons

Using a siphon is a well known way of emptying liquids from very large containers.

Fill a plastic tube with water, pinch the two ends with your fingers to keep the liquid from escaping, and put one end in a bucket of water standing on a table. Place the other end in an empty bucket standing on the floor. Now release both fingers. What happens? The water will flow up the plastic tube, through the bend at the rim of the bucket and drop into the bucket on the floor. You have made a siphon.

Air pressure does the trick, plus the difference in the weight of the two columns of water in the tube (one length must be longer than the other, and the water bucket must be higher than the empty bucket). When the water flows out of the lower end, air pressure acting on the water in the upper bucket pushes it up the tube to fill



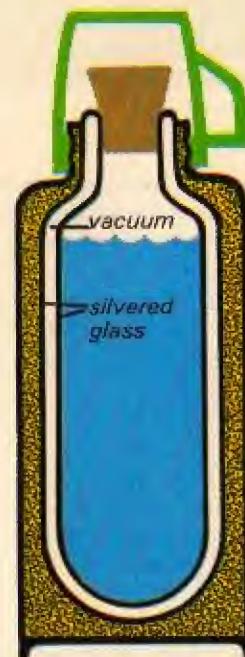
the empty space that would otherwise occur at the top of the bend. This empty space is called a *vacuum*.

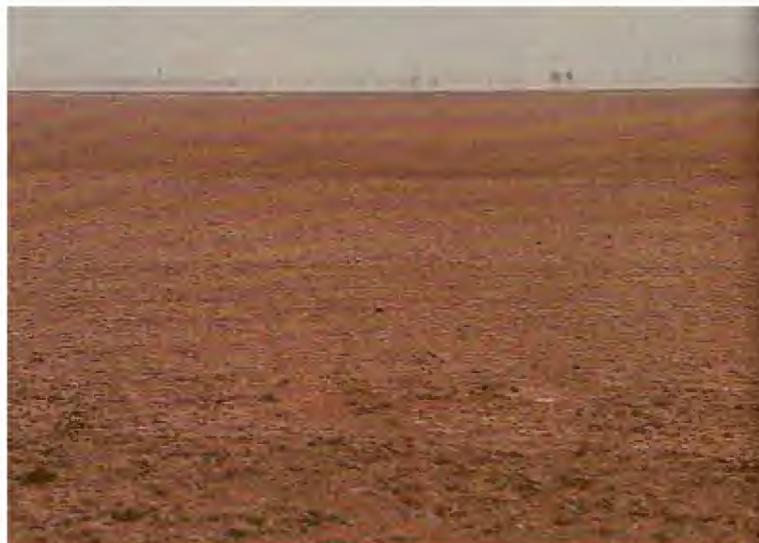
Using a siphon is the best way to empty a tropical fish tank, because you can remove the water very carefully without disturbing the plants or the gravel at the bottom of the tank. A sucking action is created at the bottom of the tube inside the aquarium and if you are careful, you can move the tube along just on top of the gravel and suck up any material that is decaying.

It works just like an underwater vacuum cleaner!

Vacuum flasks

Around 1890 a Scottish scientist called Sir James Dewar (1842-1923) invented the vacuum flask. Do you have a vacuum flask at home? If so, take a look at it. You will see that the flask has a metal or plastic case. Inside is a glass or metal bottle which has double walls. There is a vacuum (that is, a space with no air at all) inside the walls, and this prevents the heat from moving away from the hot drink poured inside. The inner surface of the outside wall is silvered to reflect any heat that may be lost, and the bottle is surrounded with cork or cardboard. The bottle mouth is closed with a stopper and the casing has a screw top which is used as a cup.





a typical desert mirage

Hot air

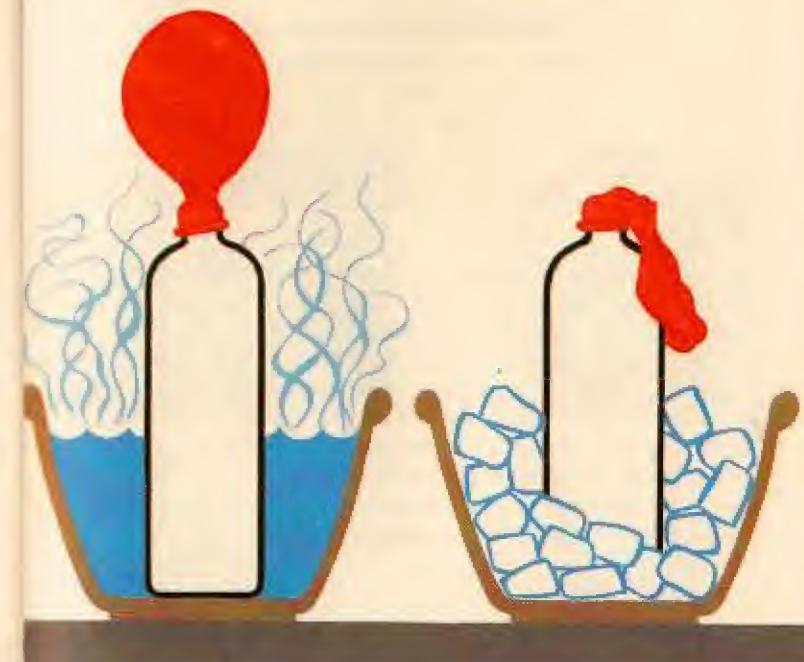
Have you noticed sometimes, on sultry, sticky days, how hot air seems to make objects quiver and shake when you look at them? If you walk up a hill on a tarmac path on a hot summer's day, the quivering effect can be quite startling. The horizon seems to shake, and everything close to it looks wobbly. Travellers in hot desert-regions of the world sometimes get confused and think they are approaching an oasis, because they see water and palm trees in the distance. As they get near their hopes are dashed because the vision fades. It is only an air picture or *mirage* of an oasis far away below the horizon. Rays of light from the oasis are reflected back by a layer of dense air above the hot light air next to the sand. This higher layer of air acts like a mirror, and as it is above the object it reflects, this object appears above the horizon within seeing distance of the thirsty travellers, when, in reality, the oasis is perhaps not only out of sight but many kilometres away.

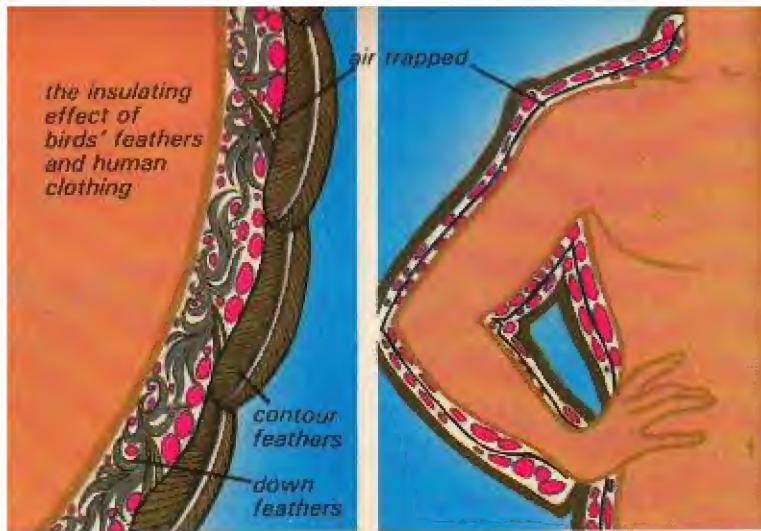
Cold air

How many times have you heard the complaint: 'Oh, I feel a draught! My feet are freezing!'

Draughts are a nuisance. There is nothing more irritating than a cold draught creeping silently into a room where you are watching television or reading a book. Cold air gets under doors and through the bottoms of windows. This draughty air is cold and heavy, but rises when it is warmed by the fire or radiator in the room. As it rises, it pushes away the warm air that surrounds our bodies and we feel cold and shivery.

We can show experimentally how air expands and contracts when the temperature varies. Get a clean, dry, plastic container and fix a balloon to its neck. Stand it in a bowl and add some hot water. What happens? Now replace the hot water with ice, and see the difference.





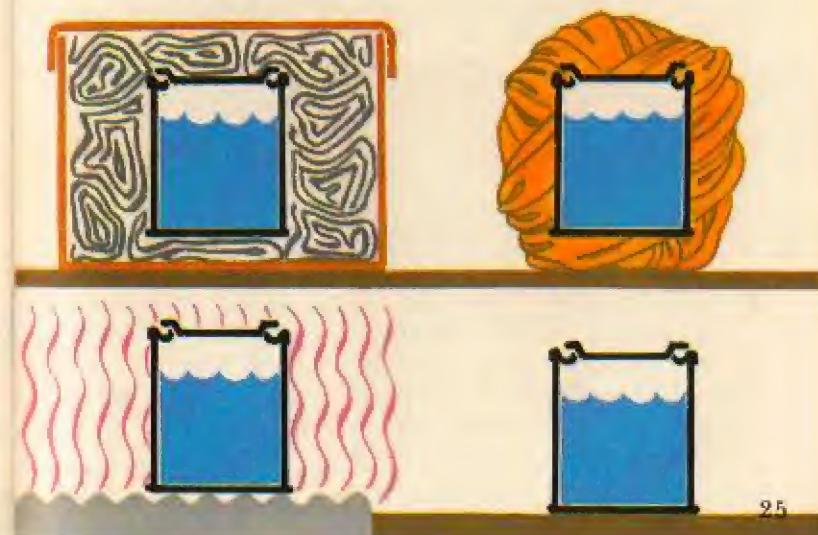
Insulation

We all feel the cold. Cold air robs us of warmth if it gets close to the skin. Furry and feathered animals have a remedy for the problem of losing body heat. They keep warm in winter by trapping air in their fur and feathers. This 'air coat' heats up as it takes heat from the animal's body, and soon the animal is totally surrounded by a warm cushion of heated air. This use of air is called *insulation*.

We wear clothes for the same purpose: to keep a layer of air trapped next to our skin to keep us warm and comfortable. In very hot countries the principle works in reverse. Air is trapped next to the body which is colder than the outside temperature, so our bodies remain cool and comfortable. When climbing mountains or exploring Arctic regions, biting winds can push away this air wrapping, so it is important to tie cuffs and trousers so that the wind can't get in. Mountain winds can be so chilling they can kill the unprepared climber or hiker.

Nowadays we have to conserve energy, so as well as insulating our bodies we insulate our homes. Houses are wrapped up in several different ways to reduce heat loss. Walls are filled with foam, lofts are lined with soft material, and hot water pipes and water containers are covered with jackets to prevent the heat from escaping.

You can experiment to show the effects of insulation. Collect four tins, all the same size. Put the first tin in a cardboard box and surround it with newspaper so that it is packed quite snugly. Take the second tin and wrap some warm clothing material around it. Place the third in the warmest spot in your house (perhaps on top of a radiator). The fourth is placed on top of the kitchen table. Fill all of them with hot water, put their lids on, and leave for thirty minutes. At the end of this time, check the water in the tins with your little finger, or a thermometer if you have one. Is there a difference in the temperatures? Which tin was insulated the best? The best insulation prevents the air surrounding the tin from getting away, and so keeps the water warm for a longer period of time.



Air and the weather

Wind is air on the move. If you blow up a balloon and take your finger away from the end, the air rushes out. You fill the rubber skin with air under pressure. By blowing hard, you force more and more air in, stretching the skin of the balloon. The air pressure inside the balloon is higher than the air pressure outside, so when the air finds an opening, it rushes out to where the pressure is lower. When this happens in nature it is called a wind.

Just as air moves from the balloon, so air moves from the cold oceans to the warmer land on hot days. This air movement, when gentle, is called a breeze. At night, when the sea is warmer than the land because of the heat it has absorbed from the sun during the day, the breeze blows the other way.



*air movements during day-time and night-time
near the sea*

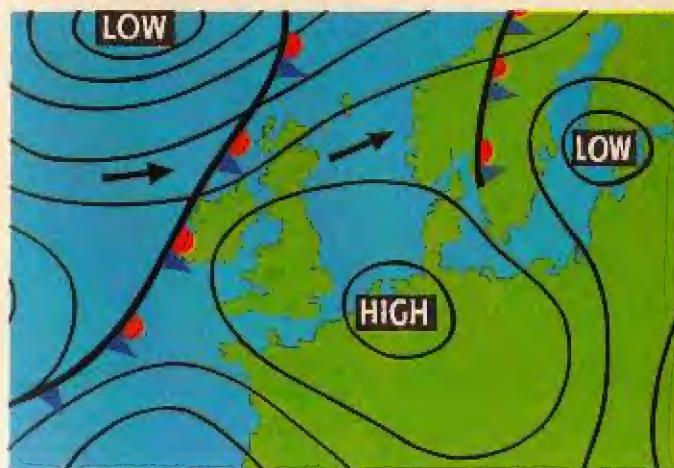
Air pressure and air temperature vary on land and sea, causing winds to blow all over the surface of the world. Some of these pressure and temperature differences create steady winds that blow for long periods of time. During the days of sailing ships, every captain knew the Trade

Winds and followed their paths across the oceans. The Northern and Southern Hemispheres are separated by low pressure areas called the Doldrums, where there is little or no wind. Many a sailing vessel has been becalmed there.

Weather forecasting

Weather stations and weather ships around the world make daily measurements of weather conditions. They measure temperatures, rainfall, wind speeds and directions, air pressures and other weather features with various instruments. This information is sent to local weather forecasting stations. From the information they receive, the Meteorological Centre at Bracknell in Berkshire prepares the weather report which is then transmitted on the radio and television and published in the daily newspapers.

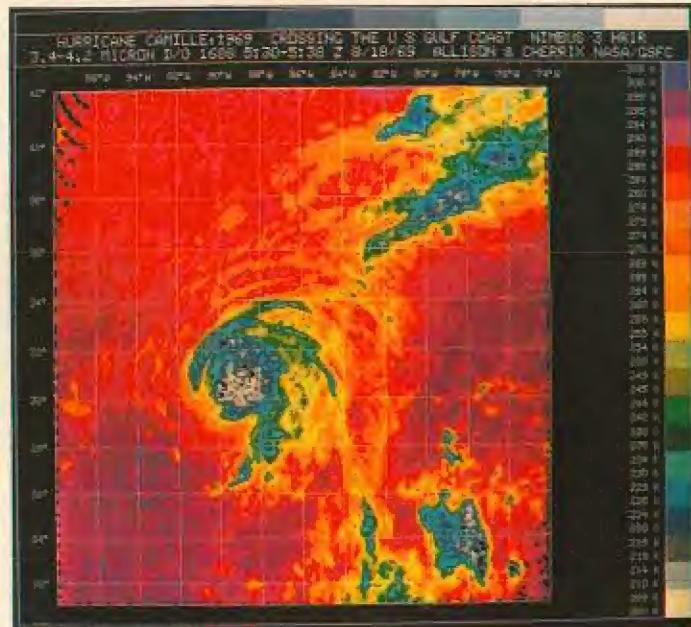
All the weather information is plotted on to maps, some of which show the British Isles and others all of Europe and the Atlantic Ocean. Using these maps, weather forecasters predict the weather reasonably accurately. Long range forecasts are not so easy to make because of the quick changes in air pressure and temperature.



Gales, hurricanes and tornadoes

Wind varies in strength and speed according to other weather conditions. Admiral Sir Francis Beaufort (1774-1857) introduced a scale of wind strengths which is still used today and is known as the Beaufort Scale. You will hear it mentioned on the shipping forecasts on radio weather reports.

FORCE	SPEED	STRENGTH	EFFECT
0	under 4 kph	calm	smoke rises vertically
1 - 3	4 - 24 kph	light breeze	small branches move
4 - 5	24 - 46 kph	moderate wind	small trees sway a little
6 - 7	48 - 74 kph	strong wind	big trees sway a little
8 - 9	76 - 110 kph	gale	chimney pots and slates fall off
10 - 11	112 - 150 kph	storm	widespread damage
12	above 150 kph	hurricane	DISASTER!



a hurricane in the Caribbean, shown on a computer

Gales

Gales can cause great problems at sea, sometimes sinking small boats. The word probably comes from the Danish 'gal', which means mad or furious. A gale is much stronger than a breeze but lighter than a storm.

Hurricanes

The strongest wind measurement on the Beaufort Scale is a hurricane. The word comes from 'huracan', which is a West Indian word. Spanish and Danish explorers first experienced hurricanes in the 15th and 16th centuries in the Caribbean. They introduced the word into European languages and it is now widely used for high winds in other regions of the world.



Tornadoes

'Tornado' is Spanish for 'turning about'. A tornado is a violent and frightening whirlwind which is usually formed in a thunderstorm and is a quite common occurrence in the U.S.A.

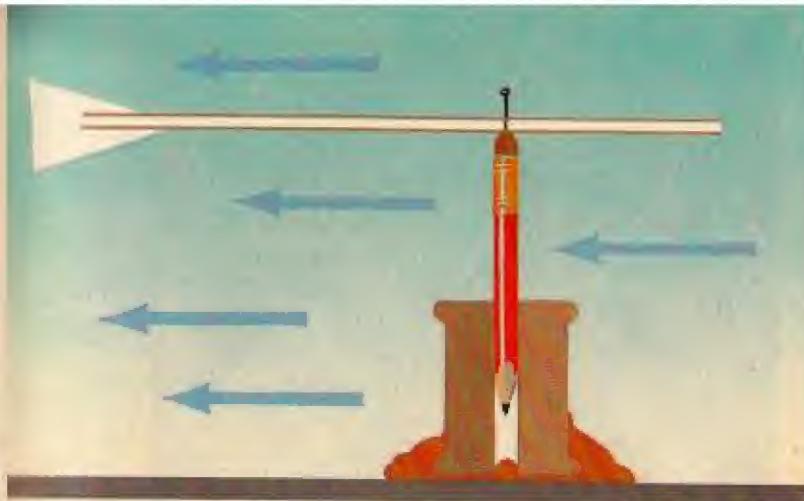
A tornado looks like a funnel-shaped cloud, moving at between 40 and 80 kph. It can last up to an hour, causing terrible devastation, ripping down trees and fences and damaging buildings.

Making a wind vane and an anemometer

Catching the wind is fun. You can't catch it in your hands because, being air, it slips through your fingers. If you run with a large, open polythene bag, you can easily catch the wind. If you run against the wind with your coat open, it acts like the polythene bag and puffs up when full. Measuring the speed of wind is difficult because wind is not consistent, for ever changing speed and direction. It is, however, fun to try. The next time it is really windy, blow up a balloon and let it go freely with the wind. When you see which way it is going, try to time it over a given distance and work out the approximate speed. Then consult the Beaufort scale on page 28. Is there a breeze, or a strong wind? You have made a simple form of anemometer, an instrument used by meteorologists for measuring wind speed.

What about wind direction? Look at the buildings where you live. You may see unusual and ornate wind vanes on churches and other important buildings. Even though wind can swirl and change direction, making a wind vane can be interesting and worthwhile.

You will need a drinking straw, a pencil with a rubber at the end, a cotton reel, some 'Plasticine', some lightweight paper and glue.



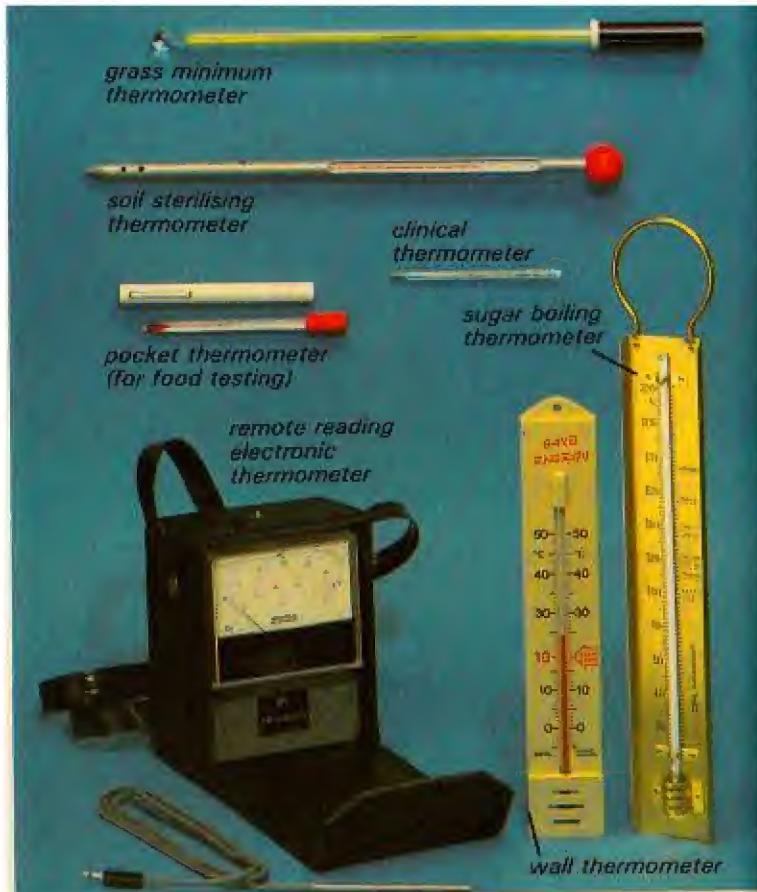
From the lightweight paper, cut a small arrow shape and fit this into a slit at one end of the horizontal straw.

Fix the reel with 'Plasticine' so that it doesn't fall over, then push the pencil through the centre hole. Then push the pin through the centre of the straw and into the rubber. Mark on the reel: N (north), S (south), E (east) and W (west).

In the morning, see where the sun rises. (Remember, it always rises in the east.) Position the wind vane on a flat surface – like a wall or fence – and watch the pointer turn in the wind. Wind direction is always stated as the direction from which it is blowing. Therefore a south wind is blowing FROM the south, a north wind FROM the north.

Wind socks

Some small airfields have special wind vanes called wind socks. These are long, brightly coloured fabric socks which hang from the top of a wooden pole. In high wind they stream out horizontally, showing pilots the direction of the wind.



Thermometers

Air temperature is measured by an instrument called a thermometer. Thermometers measure in degrees, either on the Fahrenheit or Celsius scale (F or C). The boiling point of water is 212° F or 100° C, and the freezing point, 32° F or 0° C.

The first temperature measuring instrument was made during the 16th century by Galileo, the famous Italian

scientist. His air thermometer was crude in design and very different from the thermometers we use nowadays. Galileo used a vertical glass tube standing in a shallow bowl of water. At the top of the tube was an air-filled bulb. Changes in air temperature affected the air in the bulb and caused the water to rise or fall in the tube. Unfortunately, the water in the bowl was also affected by air pressure. This made the instrument rather inaccurate.

Mercury is used in most thermometers now because it has a high boiling point (over four times greater than water) and a very low freezing point. Household thermometers have coloured alcohol in the tubes because they do not need to record a wide extreme of temperatures. Can you find out why different temperatures are important in cooking?

Doctors use a clinical thermometer. This instrument is placed under the tongue to see whether your body temperature is normal, high or low.

It's fun to check around the house to discover the warm spots with a thermometer. Make a list of the warmest and coldest areas of your home.

A maximum and minimum thermometer records the highest and lowest temperatures reached over a period of twenty four hours, giving important information to people measuring the weather. Meteorologists keep long term records of the highest and lowest temperatures in the day and night and use the information for weather predictions. The temperatures are marked in the maximum and minimum thermometer by two movable metal indicators which are reset by a small magnet. You can sometimes see such thermometers in greenhouses, where temperature is important.

Meteorologists use electric thermographs which automatically read the air temperature and record it on rotating drums. This gives the weather men a continuous record of temperature changes.

The barometer

Weather conditions are important to us all in one way or another. Weather observers throughout the world measure and exchange information every day about weather conditions. Getting reliable information that predicts changes in the weather gives an opportunity to plan and prepare for what is going to happen. It helps farmers, sailors and sportsmen to avoid the worst and make the most of conditions to come. People used to rely on superstition and folk-lore for weather forecasting.

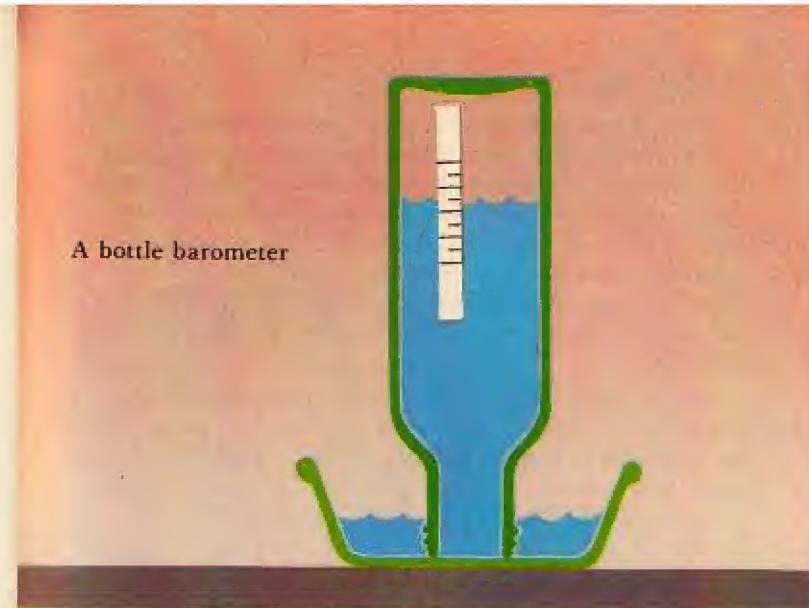
'Red sky in the morning, sailors take warning; Red sky at night, sailors' delight' is an old saying based on repeated observations by country folk.

Air pressure affects the weather. The pressure of the air can be measured by an instrument called a *barometer*. A barometer is a simple instrument to read. As the air pressure changes, a needle moves round a dial which is marked Rain, Showers etc., so that we can read out the changes in weather. A barometer is a weather guide that we can make at home.



Stretch a piece of balloon rubber over the mouth of a small jam jar. Rub petroleum jelly between the glass and rubber to make sure it is airtight. Glue one end of a small flattened straw to the centre of the rubber. As air pressure changes, the rubber will move and the straw pointer will record the movements. Make a scale on a lollipop stick standing in 'Plasticine' so that the pointer can indicate whether the pressure is up or down.

A bottle barometer



Fill a bottle three-quarters full with water and stand it upside down in a small dish of water. Changes in air pressure will affect the level of the water in the bottle. Stick a small piece of paper on the outside of the bottle and mark the water level on a fine day and then on a wet day. If the level rises, it means good weather. If it drops, it will probably rain!

You have made two simple barometers. Which one works the best? Both will show changes in the weather. Take a look at a commercially-made barometer. What are the markings on it? The words on the dial, STORMY, RAIN, CHANGE, for example, indicate different weather conditions. A steadily rising barometer is an indication of improving weather conditions, whereas a falling barometer usually means that a change for the worse is on the way.

Water in the air

When steam gushes out of the spout of a boiling kettle, it changes to water when it touches something cold. Steam is moisture in the air and is called water vapour. Try this simple experiment the next time you have a cup of tea. Put the palm of your hand over the rim of the cup for about one minute. Take your hand away and look at it. What has happened? Hot water vapour rises as a gas from the tea and changes or *condenses* into water on your cold skin.

Meteorologists think water vapour is perhaps the most important part of air because it traps the heat given off by vast areas of sea and land. Without water vapour the outer atmosphere would lose heat to outer space and our planet would get so cold that many forms of life would perish.

Green plants also produce water vapour in the form of moisture. There is a simple way to show this. Tie two small pieces of garden cane together in the shape of a cross, then push into the soil of a fully grown house plant. Cover the whole thing with a polythene bag and fasten it round the plant pot with an elastic band. Put the plant



on the window sill in a sunny position and leave for a day or so. Check what happens to the bag. Can you see the small drops of water forming on the inside of the bag? The water has been produced by the plant leaves.

Hygrometer

When air contains more vapour than we are used to, we say it is humid. When it is very humid our clothes stick to our skin.

Water vapour in the air is known as *humidity*. To measure the humidity, meteorologists use a hygrometer. Some people hang a fir cone outside their house which acts like a hygrometer. Pine cones open and close according to the moisture present in the atmosphere. If the air is very humid, the pine cone opens.



Human hair is affected by humidity. Our hair actually increases in length when we wash it. Can you devise an experiment to prove this well known fact? Start with a strand of wet hair measuring about 10cm in length.



Moving air

swarm of locusts

In a breeze, many kinds of insects and baby spiders float long distances. The scourge of the garden, the aphid, is a poor flyer but cleverly uses the wind to move from plant to plant, and garden to garden. Tiny spiderlings move long distances over the countryside on a thread of fine silk, whilst locust plagues numbering millions of individuals blacken the sky when moving with the air. Flower and tree seeds are spread by wind, colonising new areas of fertile ground. The movement of air over the ideally shaped wings of birds is essential to their flight.

Air movement is an important factor in nature and can easily be investigated at home. Get a couple of ping-pong balls and pierce a little hole through each one. Carefully thread some cotton through the holes and hang the balls from a piece of wood so that they are suspended about 3cm apart. Now get a milk straw, aim between the ping-



pong balls and try to blow them apart. What happens? Can you blow them away from each other? No – you will discover that it is quite impossible. The harder you blow the more the balls come together. Why? Surely the balls should be forced apart?

As you blow down the straw, you create a moving stream of air which produces a lower pressure between the ping-pong balls. The moving air pushes aside air resting between the two balls, and the greater pressure of air outside them pushes them together.

You may want to try this fascinating and surprising experiment again. If so, cut out two thin strips of paper and fix each onto a pin like a flag. Stand them on some cork about 3cm apart and curve the flags inwards so that the tails are nearly touching. Can you blow the flags apart? What happens when you try blowing down the gap with two straws in your mouth? Does it make a difference?



Using the power of air

Air has incredible energy and strength. Strong wind movement has shaped our landscape by creating geological changes. Powerful winds uproot trees, to such an extent that severe drainage problems result, and the build-up of water over hundreds of years forms bogs. Wind drives sand over rocks and boulders, and the sand rubs the stone surfaces until they are smooth and polished. Rocks are shaped by small stones being whirled by the wind, rubbing away particles of the rock.

Catching the wind and using its power has been a preoccupation with man throughout history. Thanks to the power of the wind, trade and contact developed between nations separated by vast oceans. Ships of all shapes and sizes developed when man learned how to use



trees distorted by persistent prevailing winds



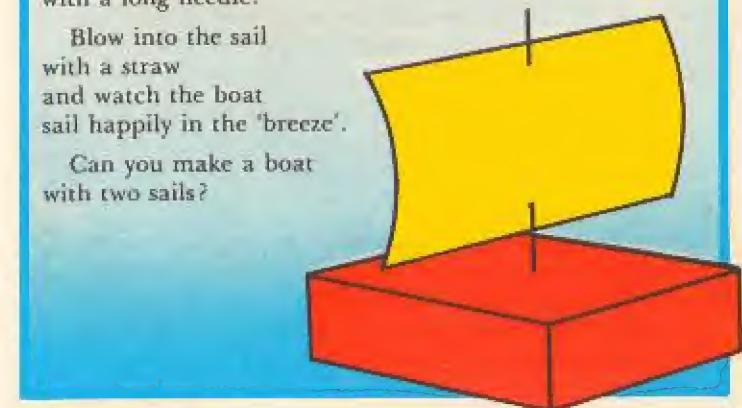
wind as a source of power to move him across water. The first sails could only take the boats in the direction the wind was blowing, but man soon mastered the most technical problem of sailing – handling the sails to take advantage of the wind blowing in all directions. More complicated sails developed enabling man to explore further afield, and the oceans filled with tall, elegant sailing boats fetching and taking goods and ideas to parts of the world isolated from the continents.

MAKING A MATCHBOX SAIL BOAT

Making a little sail boat is fun. Find a strong matchbox, make a sail from paper and fix it to the top of the box with a long needle.

Blow into the sail with a straw and watch the boat sail happily in the 'breeze'.

Can you make a boat with two sails?



Kites

Kites fly on air. Kite flying is a favourite warm weather relaxation and pastime in parks and fields throughout the world.

Kites have a fascinating history, though nobody knows who made the very first kite. Kite flying seems to have originated in Korea, Japan and China. Designs vary from the simple to the most extravagant. In China the ninth day of the ninth month each year is kite day, and the



Chinese kites

skies are filled with the most beautiful kites shaped like dragons, fish and birds. The Maoris in New Zealand use kites as a religious symbol.

A Korean general is said to have been the first person to put kites to mechanical uses when he tied a cable to the tail of a huge kite which flew over a river. This cable formed the basis of a bridge.

Kite flying for scientific purposes began in the middle of the eighteenth century. In 1752 Benjamin Franklin made his famous kite experiment by which he attracted electricity from the air during a violent electrical storm and demonstrated the electrical nature of lightning.



one of Cody's man-carrying kites

At Kew Observatory in 1847, W Birt fixed weather measuring instruments on a hexagonal kite, and in 1887, E Archibald took the first aerial photograph from a large kite. In 1901, Samuel Cody designed a kite which was large enough to lift a man. The army used it for spying during military campaigns. Cody's kites were popular with the army until they were overtaken by the development of aircraft. Cody was not deterred. In 1908 he became the first man to build and fly an aircraft in Great Britain. He died in an accident in 1913.

You can make a simple kite by following the plan at the front of this book.

Hot air balloons

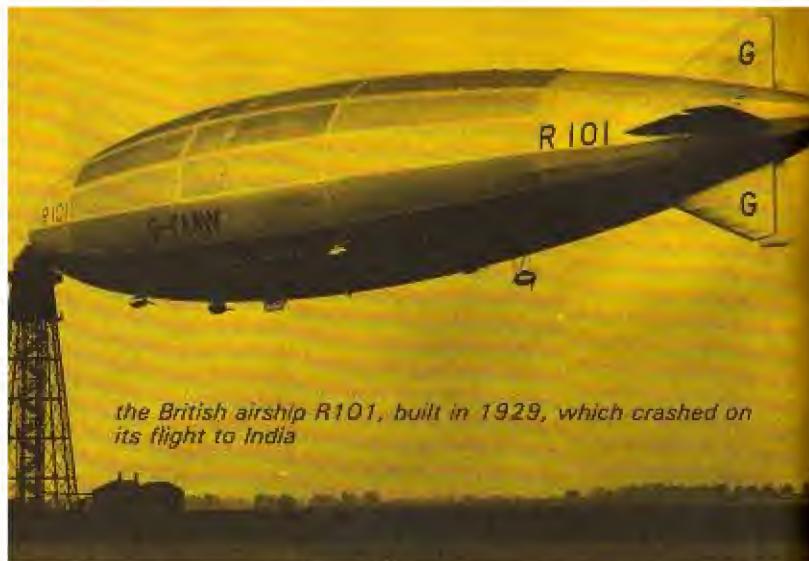
When air is warmed it increases in size, becomes lighter and takes up more space. Just what does that mean? Its importance was recognised by those who had a strong urge to fly. If you fill a balloon with hot air it will rise from the ground and fly until the air cools down. Man has designed huge balloons that carry people for enormous distances. When a balloon rises from the ground, it finds the air getting thinner and lighter, so that the difference between the weight of the balloon and the weight of the air it displaces becomes less and less. When these two weights are equal, the balloon floats at that level. The large balloons have a basket cage that houses a man with a burner to produce a constant supply of hot air. The height is controlled by throwing 'ballast' (excess weight) overboard and therefore reducing the weight of the balloon. When the balloonist wants to land he lets air out of the balloon and gently descends to the ground.

The first successful ascent by a hot air balloon carrying a man was on November 21st 1783, when Jean Pilatre de Rozier floated 9 kilometres across country. Ballooning became a popular and fashionable pastime. Soon manned balloons went higher and higher as their pilots became more confident. In 1932, a Swiss called Auguste Piccard reached a height of over 16 kilometres, and in 1935, two Americans reached a height of over 23 kilometres.

Unmanned balloons have gone even further. They are used for collecting scientific information from the upper layers of the air belt that surround the earth. These balloons carry recording instruments and when the rarefied atmosphere at great heights causes the balloon to burst, the instruments float to the ground on parachutes. They are collected by scientists who then interpret the information obtained.



manned hot air balloons



Airships

An airship is an elongated balloon filled with a lighter than air gas, and fitted with propellers and controls so that it can travel in any direction as it floats in the air. Balloons are restricted to ascent or descent, which means they can go up or down, but they can only move horizontally in whichever direction the wind is blowing. Henri Giffard (1825-1882), a French engineer, was the first man to build and fly an airship able to fly in any direction. Another man, Ferdinand von Zeppelin (1838-1917) designed an airship with a system of rudders that made the craft easy to manoeuvre. Airships were used for military purposes and during the first World War carried out bombing raids over England and France.

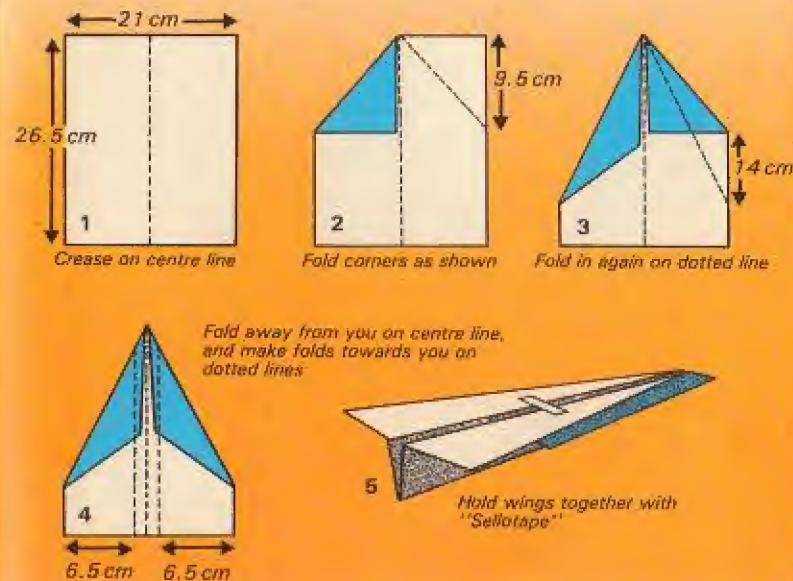
During the second World War, the United States navy had 150 airships in service against submarines in the oceans of the world.

There has been a revival of interest in them in recent years, and they are currently used for purposes such as television photography.

Gliders

Most gliders don't have engines, relying instead on air movements to keep them airborne. How do they fly? Tuck a narrow strip of paper under the top cover of a book, then hold the book horizontal. Now blow over the top of the book towards the paper. What happens? Because you blow along the top, there is lower pressure above the strip and higher pressure beneath it, because you blow the air away. As a result, the strip of paper is forced upwards. This is called *lift*. Lift means that something heavier than air can be lifted up when air moves past it. Lift keeps gliders gracefully soaring in the sky. Kestrels glide and soar using the different air pressures acting against their wings. Paper aeroplanes are similar. They are easy to make and great fun to fly.

Can you make a paper glider?



Dirty air

Over the last hundred years man has added various substances to the air. Every day, factory chimneys and car exhausts emit poisonous gases that combine and pollute the air we breathe. It is estimated that one large industrial country adds more than 150 000 000 tonnes of gas, smoke and dust to the atmosphere each year. Polluted air acts like a blanket. In the London smog of 1952, over 4000 people died of lung conditions brought on by the smog trapped in the city.



As well as unpleasant gases, the air is filled with minute flying particles of dust, pollen grains, fungal spores and tiny plant seeds. If you live in a clean air area, try the following experiment. Place a piece of paper tissue on a saucer and put it out in the rain. When the tissue is wet, bring the saucer indoors and put it on a windowsill. Add a drop of liquid fertilizer. Check the tissue after a few days. Millions of minute algae (single celled green plants) are washed from the air by rain. Some will grow on the tissue, feeding off the liquid fertilizer.

algae under the electron microscope



The absence of air

Man's strong curiosity drives him to make sense of the world in which he lives. Understanding the behaviour of air has helped him to conquer the air and space beyond. First the kite, then the hot air balloon, and making small models of gliders, showed him the problems of flight. Once the major problems of air resistance and air pressure were overcome, he realised that air actually helped his inventions to remain airborne. Eventually he designed the propeller plane, the jet and then the rocket. There is a limit for planes where the air thins out above our planet. There is not enough air to burn the plane fuel and not enough air to give the plane lift. Rocket flight overcomes the problem.

Rockets are similar to jet aircraft as they both emit hot gases which produce the thrust necessary for flight, but the rocket takes its own supply of oxygen so that it can burn its own fuel when far above the air belt that surrounds the earth. Rockets power large space craft through the skies and up into space where there is no air. They have taken man to the moon. Unmanned space craft have flown to Mars and Saturn and sent back information, through television, about the surface conditions of both planets.

VOYAGER, an unmanned spacecraft



Even though we cannot see it or smell it, air is an extraordinary substance. We depend upon it in many ways other than for breathing. Our experiments have shown us some of its well known properties and its unique value to our lives.



the 1981 space shuttle COLUMBIA

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